TITAN AMPHIBIOUS AEROVER

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ABSTRACT

A novel, robotics vehicle is presently under development at JPL that will have the capacity to fly, drive and float, as well as conduct submersible studies on Saturn's largest moon, Titan. Other than the Earth, Titan is the only other body in our solar system that is believed to contain large quantities of surface liquid, which is presently believed to be constituted of liquid methane and ethane, and it also has a significant atmosphere. The novel robotics vehicle under development takes advantage of these unusual characteristics to allow it to morph from a controlled altitude aerovehicle to an inflatable surface rover, and to a paddle-wheeled type of floating boat that carries a tethered submersible vehicle. One mission scenario under consideration is to have numerous near-surface descents of the rover while controlling altitude of an attached balloon with RTG waste heat. The combination vehicle would always travel below the upper organic haze layer, thus providing the first clear, global images of the Titan surface. After approximately one month of imaging, the rover would be gently landed in a preferred location and the tow balloon cut free. The rover would explore both solid and liquid surface areas while the balloon continues imaging.

INTRODUCTION –TITAN ENVIRONMENT

A novel, robotics vehicle is presently under development at JPL that will have the capacity to fly, drive and float, as well as conduct submersible studies on Saturn's largest moon, Titan. Other than the Earth, Titan is the only other body in our solar system that is believed to contain large quantities of surface liquid, which is presently believed to be constituted of liquid methane and ethane. With a primarily nitrogen atmosphere at 1.4 bar surface pressure and about 93K surface temperature, (Ref. 1) the density of the atmosphere at Titan's surface is about four times that of Earth's, thus making the atmosphere ideal for ballooning. For example, a 3-m diameter helium balloon (<1 kg) can easily support a 50-kg gondola payload at 10 km altitude above the Titan surface. Since the Titan upper atmosphere contains an opaque photochemical haze, it is impossible to optically image the surface from the orbit. A balloon, however, can fly beneath the haze and can take clear optical imaging of the Titan surface, which is believed to be partially covered by liquid methane-ethane seas. A balloon flying at 10 km altitude would be safely below the anticipated 14-km methane ice cloud region, and can be expected to travel with the winds at about 10 m/sec, thus encircling the moon about every 10–20 days (Ref. 1,2).

Although a super-pressure helium balloon, i.e., a balloon with an internal pressure somewhat above external ambient pressure, can fly at some constant altitude at Titan, a zero-pressure helium balloon could fly at varying altitudes and could, in fact, take numerous in-situ samples (solid, liquid, and atmospheric) from around the globe.

This paper will discuss how both super-pressure and zero pressure balloons can be used to create an amphibious aerover that could explore Titan's atmosphere, solid landmass, and liquid seas.

INFLATABLE ROVER DEVELOPMENT

A 20-kg inflatable rover, currently under development at JPL (Figure 1), was originally intended for use on Martian rocky terrains. It contains three spherical wheels that are 1.5 m in diameter, which allow the rover to easily climb over 0.5-m rocks. With raised treads, this same vehicle has been found to have excellent liquid traversability on calm lakes, similar to those anticipated on the low sunlit surface of Titan.

The present inflatable rover prototype travels at 2 km/hr on flat terrain, and uses only 18 w of power. Considering Titan's reduced gravity of 0.135 g, it would take only about 6 w of power to propel the rover at about 5 km/hr on Titan level terrain, with speeds somewhat slower on liquid surfaces.

Present rover tires being tested are fabricated from spectra or Vectran, although PBO tires would likely be required for Titan's 93K surface environment.

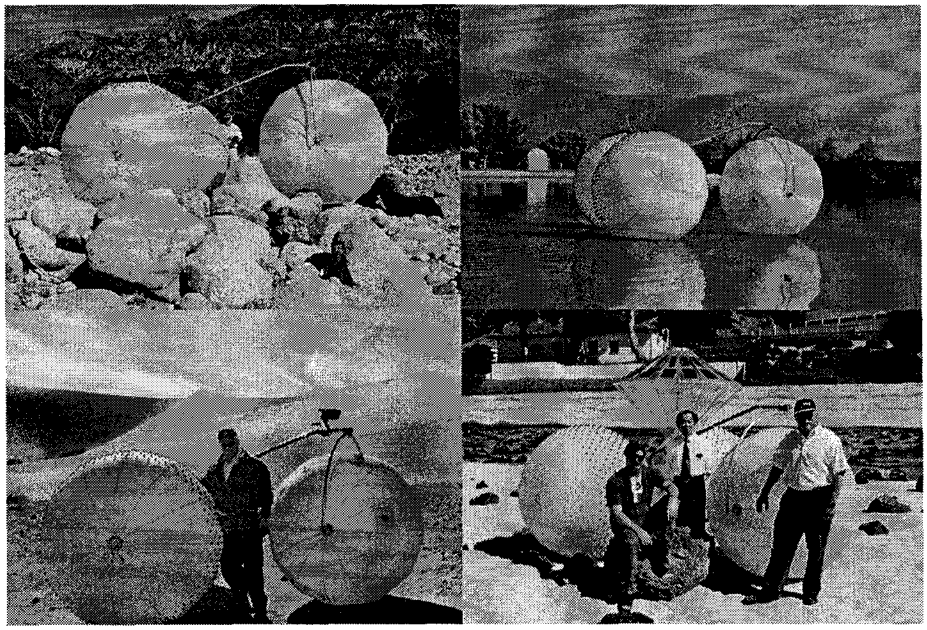


FIGURE 2: **THE INFLATABLE ROVER DRIVES ON ALL TERRAINS**

TITAN BALLOON BUOYANCY TECHNIQUES

Venting / Ballasting

One of the most common means to control helium balloons on Earth is to use venting and ballasting. With this technique, helium balloons will descend when some helium is vented, and they will ascend when some ballast is dropped off. By using the inflatable rover's tires as balloons, it is possible to vent some tire pressure causing descent to the Titan surface. After dropping off some ballast, such as a surface science experiment, the rover can then re-ascend (Figure 2). This could be done a number of times before the rover eventually becomes too heavy to lift off with the remaining helium. At this point the rover's tires could exhaust their remaining helium, and the tires could be filled with the primarily nitrogen ambient atmosphere. The rover could then act as an atmosphere vehicle that travels over solid land as well as on the anticipated liquid methane-ethane seas.

Phase Change Fluid

Previous studies (Ref. 4) have shown that a number of fluids can be used as buoyancy control at various planets by means of condensing the fluid in the atmosphere's upper altitudes and boiling the fluid in the planets lower altitudes. The result is that the balloon continually bobs about the altitude where the condensing fluid changes phase. Numerous tests have been conducted using Refrigerant 114 and other fluids for Earth tests where the balloon bobs around 7 km, and argon has been proposed as a phase change

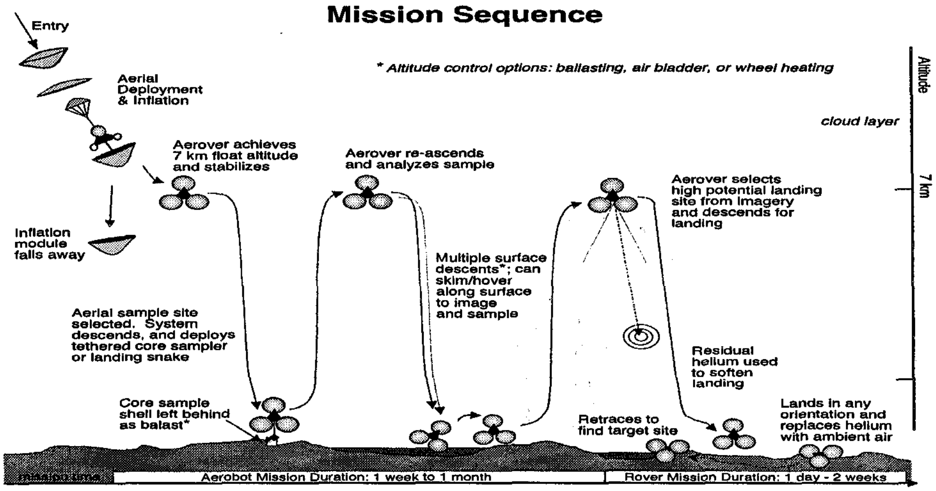


FIGURE 2: MISSION SEQUENCE

buoyancy fluid for Titan (Figure 3), where the balloon may also bob around some low altitude. There is a problem, however, in that the exact atmosphere characteristics are not presently known on Titan, and thus a TBD mixture may be required, that is made from two or more of the following fluids: oxygen, nitrogen, carbon monoxide, and argon.

For this altitude-varying technique, the rover's tires could be used as helium balloons, or a separate helium balloon could carry the rover as a payload that is eventually deployed.

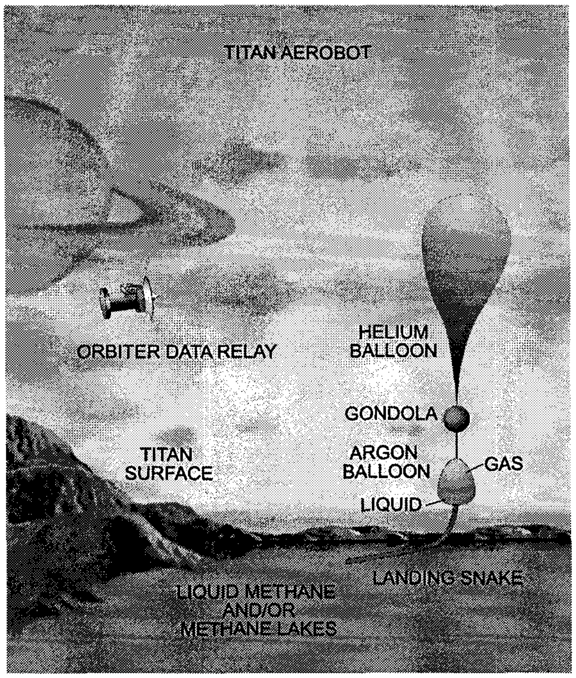


FIGURE 3: TITAN AEROBOT

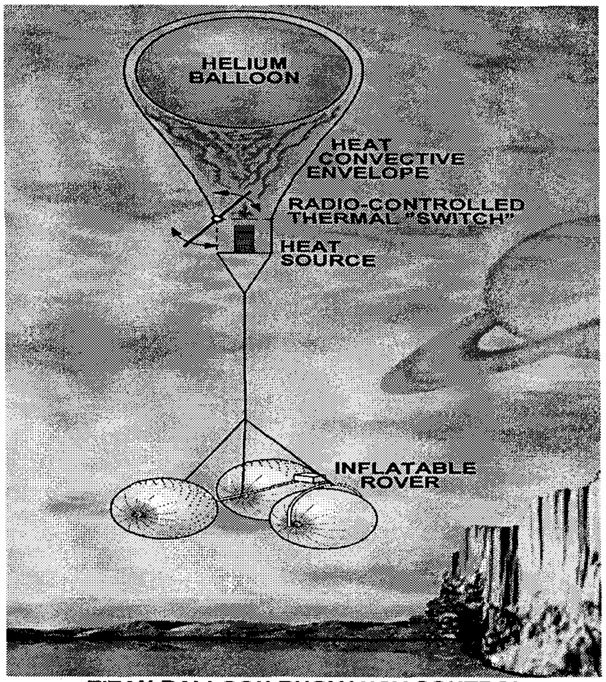
Energy-Generated Buoyancy Changes

A number of energy-generated buoyancy changes are possible, which involve either compressing gas with a mechanical compressor, or using radio-isotope thermal generators (RTG) waste heat. These systems include:

1. Helium balloon with RTG-powered hot air (N_2) balloon
2. RTG-powered hot helium balloon
3. Compressed air (N_2) inside a bladder
4. Liquefied air (N_2) inside a container
5. RTG-heated, sorbent material
6. RTG-heated Rozier balloon
7. Condense atmospheric methane with a mechanical cooler

Analysis has been performed on each of these systems, and the optimal energy-generated buoyancy technique for Titan appears to be using RTG waste heat to warm a Rozier-type balloon, i.e., a helium balloon with a warm, ambient-atmosphere balloon below it (Figure 4).

In this Rozier-type balloon, RTG waste heat is diverted to either ambient or to a convective envelope beneath the helium balloon. The Rozier system has a very high buoyancy change (15%) and a relatively quick characteristic time to fully change buoyancy (12



TITAN BALLOON BUOYANCY CONTROL
ANALYSIS AND DEMONSTRATION

FIGURE 4: TITAN BALLOON BUOYANCY

minutes). Furthermore, the system helps reduce the chance of methane ice formation (<90K) on the balloon. Analysis has shown that altitude control is possible to within ± 20 meters with this type of buoyancy control system.

The proposed buoyancy method shown in Figure 4, is similar to a hybrid hot air/hot hydrogen balloon, as flown by Pilatre de Rozier in the 1790s. Unfortunately, for Rozier, his hydrogen balloon exploded, causing him to be anointed as both the first pilot of a lighter-than-air balloon, as well as the first casualty. The hybrid design is, however, basically safe when used with helium, as was done with "Solo Spirit," the World's first around-the-globe balloon attempt piloted by Steve Fossett in 1998, as well as with the first successful around-the-globe flight by the Breitling Orbiter Team in 1999.

SUMMARY AND CONCLUSIONS

The thick atmosphere of Titan is ideal for ballooning, which could provide global imaging of the moon's surface below the opaque upper atmosphere organic haze. A number of amphibious flying rovers, or amphibious aerovers, appear possible to explore Titan's atmosphere, solid land masses and anticipated liquid methane-ethane seas.

The simplest method is to fill the tires of an inflatable rover with helium. Simple venting of small amounts of helium would allow descent to the surface, while dropping ballast, such as experiments, would allow re-ascent. When re-ascent is no longer possible, the rovers tires could be filled with ambient atmosphere to provide transportation over both liquid and solid surfaces.

Another method of balloon buoyancy for the rover may be possible by using argon, or a gaseous nitrogen-oxygen mixture in combination with a helium balloon. Descent to low altitudes causes the fluid to boil, thus filling a secondary balloon and causing descent. The specific condensable fluid chosen cannot be selected, however, until the Huygen's probe makes more precise measurements of Titan's atmosphere.

A third method of rover balloon buoyancy control is to use waste heat from an RTG to heat ambient atmosphere beneath a helium balloon. This Rozier-type balloon, using propane heat, is common among Earth long duration balloonists. Altitude control to within ± 50 m appears quite possible, and the likelihood of methane ice formation below 90K is much less likely.

ACKNOWLEDGMENTS

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